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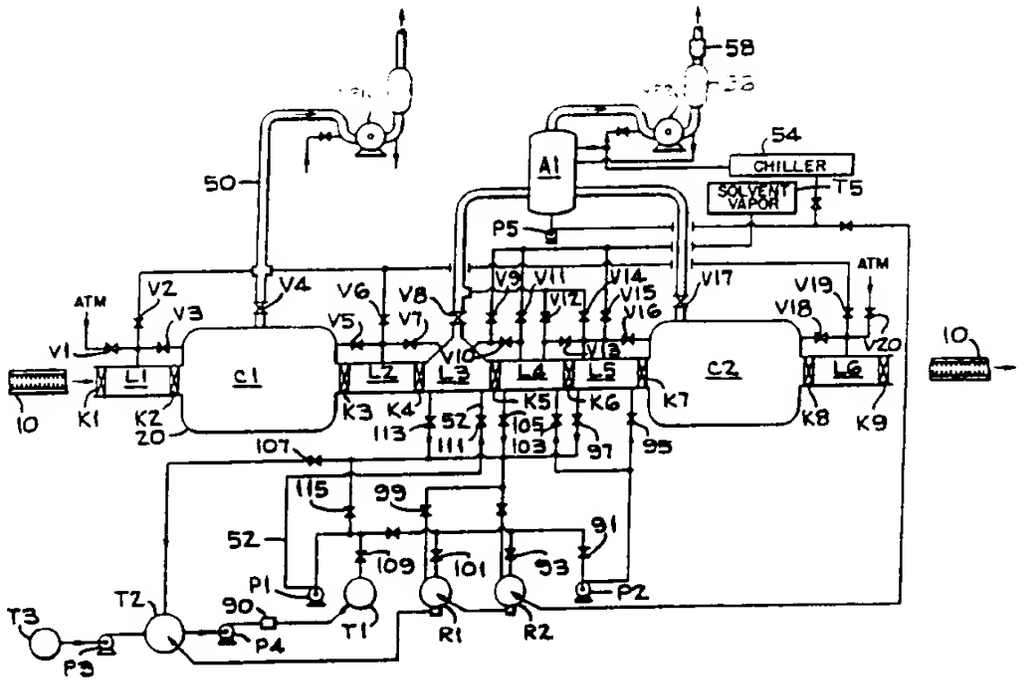

(57) Abstract

A process and apparatus for the deacidification and removal of moisture and/or solvent from books. Containers of books (10) are moved by conveyor (42) into a drying chamber (C1) where the books are dried under vacuum dielectric heating (22, 24). The conveyor (42) moves the containers of books (10) to a lockhopper (L3) filled with a solution of deacidifying chemical compounds in a solvent. After the books become saturated with the solution, the conveyor (42) moves the container of books (10) to a rinse lockhopper (L4) where the books are rinsed with solvent, and then to a chamber (C2) where solvent is removed from the books under vacuum using dielectric heating.

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BOOK DEACIDIFICATION METHOD AND APPARATUS

This invention relates to methods and apparatus for the preservation of books, manuscripts, documents and other printed records by neutralizing the acidity of the paper on which they are printed.

For more than 100 years the processes commonly employed to manufacture paper have resulted in a product which contains acid forming chemicals. Over time acid paper turns yellow, becomes brittle and eventually disintegrates. Books have been made with such paper. As a consequence, almost all of the libraries in the world are in danger of losing a vast majority of their collections. Certainly, almost all books printed in the past 100 to 150 years will disintegrate unless treated to neutralize the acidity in the paper. The problem has been recognized for some time, as evidenced by a recent study "Mass Deacidification for Libraries" by George Martin Cunha printed in Library Technology Reports, Volume 23, No. 3 May - June 1987, which reported all prior methods of mass deacidification. Two elements of the problem are evident; one being the potential detrimental effects of the chemicals employed in the process, such as causing certain types of ink to run, for example, and the other being the time required to process a book. Whatever chemical process is employed, the time element is critical. Not only are there literally millions of books that must be deacidified, but also disintegration is being accelerated by acids carried by or produced from air-borne pollution, such as vehicle exhausts, that has increased dramatically in the past few decades. The processes for deacidification have required the removal of moisture and/or a solvent from the books. Since paper has good

insulating properties which slows the transfer of heat, drying times consume a major portion of the total process cycle time.

The present invention addresses the one element of the deacidification process and provides a method and apparatus that rapidly removes moisture or solvent and thereby reduces the total cycle time required to deacidify a book load. The present invention also subjects the books being processed to minimal stress, thermal as well as physical, processes each page of every book uniformly, and requires no preconditioning or inspection prior to being processed. This invention further provides an efficient and orderly processing of library books, minimizing the physical handling required to prepare them for processing and to return them to the proper place in the library shelves, as well as ensuring the integrity of the collection. This invention is also particularly suited to process large quantities of books.

These and other attributes of the present invention, and many of the attendant advantages thereof, will become more readily apparent upon a perusal of the following descriptions and the accompanying drawings, wherein:

Figure 1 is a schematic representation of a preferred embodiment of apparatus for the mass deacidification of books;

Figure 2 is a vertical section, taken on the longitudinal centerline, of a portion of a dielectric dryer included in the apparatus of Figure 1;

Figure 3 is a cross-section view taken on line 3 - 3 of Figure 2;

Figure 4 is a vertical section, taken on the longitudinal centerline, of a lockhopper included in

the apparatus of Figure 1; and

Figure 5 is a cross-sectional view taken on line 5 - 5 of Figure 4.

Referring now to Figure 1, containers or trays 10 filled with books are conveyed into an entrance lockhopper L1 through a knife valve K1 which may be closed to isolate the lockhopper L1 from atmosphere. A knife valve K2 is provided at the other end of the lockhopper L1 and provides a seal between the lockhopper L1 and a drying or vacuum chamber C1. The drying chamber C1, as shown in Figures 2 and 3, includes a shell 20 capable of sustaining a vacuum and upper and lower electrodes 22 and 24 of a dielectric heater. The upper electrode 22 is supported from the shell 20 by standoffs 26 made of dielectric material such as ceramic. The lower electrode 24 is supported by brackets 25 secured to supports 28 and is grounded through the brackets 25 to the supports 28. Both electrodes 22 and 24 are preferably made of perforated aluminum. A power supply 30 supplies high voltage direct current, e.g. 2000V. DC or higher, through a conductor 32 to a radio frequency power generator 34. The RF power produced by generator 34 is fed to a supply conductor 36 through an appropriate RF power feed-through 38 which maintains the vacuum integrity of the shell 20 while permitting transmission of the RF energy. The conductor 36 connects to the upper electrode 22 which must be tuned by the stubbing inductors 40 connected between the electrode 22 and the grounded shell 20. The aforementioned tuning is achieved by providing the proper number of coils or turns in the stubbing inductors 40. The frequency is in the RF power spectrum in the range of 5 MHz to 27 MHz. A conveyor belt 42 made of a dielectric material, e.g. silicon rubber, is trained over a pair

of rollers, the powered one of which is shown at 44. A shaft 46 is affixed to the roller 44 and is rotatably supported by supports 28 and driven by a motor 48. The belt 42 extends over the lower electrode 24 and is capable of transporting the containers 10 toward the right as viewed in Figure 2.

The drying chamber C1 is connected with a vacuum pump VP1, which preferably is of the liquid-sealed type that is capable of pumping mixtures of air and water vapor, through a conduit 50. The residual moisture in the books, which typically is 6 - 7% by weight for shelved library books, is reduced in the vacuum chamber C1 to between 0.5 and 2.5%. This reduction in moisture is achieved by heating the books, while subjected to vacuum pressure, in the dielectric field between the electrodes 22 and 24. The dielectric field will produce uniform heating of the books at a temperature below the boiling point of water at the lower vacuum pressure. Since the books must not be heated above 60 - 65°C, the vacuum pressure, which is 10 - 30 inches of mercury, keeps the book temperatures below this maximum, while also removing the moisture from the chamber C1. The allowable lengths of the electrodes in the drying chamber C1 will be limited by the frequency of the RF power used in the dielectric heater. Uniformity of RF field and of heating is best achieved by avoiding creation of standing waves within the chamber C1. As the lengths of the electrodes in the chamber C1 increase, lower frequencies having longer wavelengths are required where uniform heating is desired throughout the chamber C1.

An isolation lockhopper L2 is connected with the drying chamber C1 and has a knife valve K3 and K4 at each end. This lockhopper assures a complete

separation between the moisture or water portion and the solvent portion of the apparatus. A saturation lockhopper L3 is connected with the isolation lockhopper L2 and two rinse lockhoppers L4 and L5 are connected in series with the lockhopper L3. Knife valves K5 and K6 are capable of separating these lockhoppers. A liquid pump P1 is capable of filling the lockhopper L3 with a solution of deacidifying chemical compounds such as disclosed in U.S. patent application Serial No. 252,421 filed September 30, 1989, for example, dissolved in a solvent, such as trichlorotrifluroethane or hexane, for example. The pump P1 draws this solution from tank T1 and delivers it to lockhopper L3 through conduit 52. As the books are hot from the drying cycle, some of the solution will boil off and a space is desirably provided at the top of the lockhopper L3 to assure separation between the solvent liquid and vapor. The books may be agitated or the solution may be circulated to improve the penetration. When the books in the lockhopper L3 are saturated, the solution is drained to tank T2 and a vacuum drawn by vacuum pump VP1. The solvent vapors pass through an absorber A1 where they are condensed by circulation of cold solvent which is cooled by chiller 54 and circulated by pump P5. A carbon filter 56 is interposed in the outlet side of pump VP2 to remove traces of solution vapor. A small back pressure is maintained by back pressure check valve 58 to prevent backflow of ambient air into the filter 56 and other parts of the system.

The lockhopper L3, which is similar to all other lockhoppers, is shown in Figures 4 and 5. A conveyor belt 60 is trained over a powered roller 62 and an idler roller 64. A support plate 66 maintains the upper run of the belt 60 level for support of the

containers 10 filled with books. The books may be packed in open trays, but preferably are packed into containers 10. The containers 10 include a bottom or case 70 and a lid 72, both of which are liberally provided with openings to permit solvent vapor to exit and liquid solvent to enter into and drain from the container. The books are taken from the library shelf, and placed in order in the case 70 on their spines; the case 70 being at the time inverted from the position shown in Figures 4 and 5. The lid 72 is placed on case 70 and sealed to protect the integrity and order of the collection. The end of the case 70 opposite the lid 72 is smaller in dimension than the end adjacent the lid 72 so that when the containers 10 are inverted to rest on the lid 72 the free end of the book will have an opportunity to open slightly. This facilitates penetration of the solution and escape of the moisture or solvent vapor. The books will have a tendency to float upward when the lockhopper L3 is filled with liquid. In order to limit upward movement of the container 10 and to assure proper orientation on the conveyor belt 60, an inverted U-shaped guide member 74, which is open at each end to permit movement of the containers 10 by the conveyor belt 60, is engageable with the container 10. The rod 76 is attached to the member 74 and extends through a seal 78 in the top wall of the lockhopper L3 and may be oscillated and/or agitated vertically to facilitate movement of solution through the books in the container 10. Alternately, agitation may be accomplished by circulating the solution through the lockhopper.

The rinse lockhopper L4 is connected with a pump P2 which pumps a rinse of solvent from rinse tanks R1. The pump P2 provides a second rinse from

rinse tank R2 into lockhopper L5. The concentration of compound in the solvent decreases from tank R1 to tank R2. Excess compound is thereby removed from the books. A solvent removal chamber C2 connects with the rinse lockhopper L5 with a knife valve K7 therebetween. The chamber C2 is similar to drying chamber C1 and heats the books by means of a dielectric field while subjected to the vacuum from vacuum pump VP2. An exit lockhopper L6 connects with the chamber C2. A knife valve K8 is interposed therebetween and knife valve K9 is provided at the free end of lockhopper L6.

With containers of books in all lockhoppers and in both chambers C1 and C2, with heating power on in both chambers C1 and C2, with all lockhoppers and chambers under vacuum and with all valves closed except valves V2, V4, V6, V8, V12, V14, V17 and V19, a container of finished books can be discharged from the process by closing valve V19 to isolate L6 under vacuum. Valve V20 is opened to purge L6 with air. Knife valve K9 is opened and the conveyor in L6 operated to move a finished container of books from L6. Knife valve K9 and valve V20 are then closed and valve V19 opened to permit pump VP1 to evacuate L6. The RF power to C2 is turned off and V18 opened to equalize pressure in C2 and L6. Knife valve K8 is then opened and the most forward container in chamber C2 is moved by the conveyor into L6. Knife valve K8 and valve V18 are closed and valve V16 is opened to equalize the pressure in L5 and C2. Knife valve K7 is opened and the container in L5 moved into C2 and the containers in C2 are advanced, the chambers C1 and C2 being capable of holding multiple containers end to end. Knife valve K7 and valve V16 are closed and the RF power to C2 turned on to initiate solvent removal.

Valve V13 is then opened to equalize the pressure in L4 and L5. Knife valve K6 is opened and the container in L4 is moved to L5. Knife valve K6, and valves V13 and V14 are closed to isolate L5 under vacuum from VP2. Valves 91, 93 and 95 are opened and locker L5 is flooded with clean solvent from rinse tank R2 by pump P2. When flooding is complete, pump P2 is stopped and valves 91, 93 and 95 are closed. During the rinse the books may be agitated or the solvent may be circulated. When the rinse is completed valves 97 and 99 are opened to drain solvent into tank R1. Valve V15 is also opened to assist in purging rinse solvent in L5 into tank R1 from the pressurized solvent vapor maintained in tank T5. Valves V15, 97 and 99 are closed to isolate L5 at the solvent vapor pressure in tank T5. Valve V14 is then opened to permit evacuation of L5 by pump VP2. Valve V10 is opened to equalize the pressure in L3 and L4. Knife valve K5 is opened to permit the container in L3 to be moved into L4. Knife valve K5, and valves V10 and V12 are closed to isolate L4 under vacuum from pump VP2. Valves 91, 101 and 103 are opened so that pump P2 can flood L4 with once-used solvent from rinse tank R1. When L4 is flooded, pump P2 is turned off and valves 91, 101 and 103 closed to stop solvent flow to L4. During the rinse the books may be agitated or the solvent may be circulated. When the rinse is completed valves V11, 105 and 107 are opened and the rinse solution in L4 is purged to tank T2 with assist from the pressurized solvent vapor maintained in tank T5. Valves V11, 105 and 107 are closed so that L4 is isolated at solvent vapor pressure of tank T5. Valve V12 is opened to permit pump VP2 to evacuate L4. Valve V6 is closed to isolate L2 under vacuum of pump VP1. Valve V7 is opened to equalize pressure in L2

and L3. Knife valve K4 is opened and the container in L2 is moved to L3. Knife valve K4 and valve V7 are closed and valve V6 is opened to permit pump VP1 to evacuate L2. Valves 109 and 111 are opened and the lockhopper L3 is flooded with treatment solution in tank T1 by pump P1. The treatment solution impregnates the books in L3 and vapors are removed by pump VP2. Valves 109 and 111 are closed and pump P1 is turned off to stop solution flow to L3. During the treatment the books may be agitated. When the treatment is complete valve V8 is then closed to isolate L3. Valves V9, 113 and 107 are opened to purge solution into tank T2 with assist from the pressurized solvent vapor maintained in tank T5. Alternatively, valve 115 may be opened instead of valve 107 to return the solution to tank T1. Valves V9 and 113 and the previously selected one of valves 107 and 115 are closed to isolate L3 at solvent vapor pressure as it exists in tank T5. Valve V8 is opened to permit VP2 to evacuate L3. The RF power to C1 is turned off to stop moisture (water) removal. Valve V5 is opened to equalize the pressures in C1 and L2. Knife valve K3 is opened and the most forward container in C1 is moved into L2. Knife valve K3 and valve V5 are closed to isolate L2. Valve V3 is opened to equalize the pressure between C1 and L1. Knife valve K2 is opened and the container in L1 moved into C1, while the containers in C1 are indexed. Knife valves K2 and valves V2 and V3 are closed to isolate L1 at vacuum pressure. RF power is turned on to C1 to restart water removal. Valve V1 is opened to purge L1 with atmospheric air. Knife valve K1 is opened and a new container placed in L1. Knife valve K1 and valve V1 are closed to isolate L1 at atmospheric pressure. Valve V2 is opened to permit pump VP1 to evacuate L1,

which completes one cycle.

Tank T3 contains solvent with a high concentration of treatment compound which can be metered into tank T2 by pump P3 to bring the spent solution to the proper concentration after which it can be pumped by pump P4 through filter 90 to tank T1.

Since all operations in the semi-continuous operation described above are sequential, the total process cycle time is determined by the time it takes to perform the slowest operation. Saturation of the books in lockhopper L3 and the two rinse operations in lockhoppers L4 and L5 are usually the determinates of cycle time since these lockhoppers accept a single tray or container of books. The minimum time for saturation or impregnation and for rinsing is about three minutes. The residence times for the two chambers C1 and C2 are about ten minutes. The residence time in each chamber divided by the number of containers in the chamber equals the cycle time for that operation. Making the chambers C1 and C2 longer so they will accept more trays, and increasing the size of the power supplies to match, will reduce the cycle times for these chambers.

The method of the present invention may also be accomplished by a batch process. In a batch process, only a chamber similar to C1 is necessary with the tanks T1, T2, R1 and R2 and their associated pumps connected therewith instead of with the lockhoppers. The books are placed in the chamber in the same types of containers and residual moisture reduced to the proper level by subjecting the chamber to vacuum and the books to a dielectric field. The chamber is then flooded with a treatment solution, which is then drained off when saturation is complete. The vacuum may be applied during the

flooding to promote penetration of the solution. The books are then rinsed with solvent one or more times to remove excess treatment chemicals. The vacuum is then applied to dry the chamber itself and the power is then turned on to heat the books and drive off the solvent. When dry the container of treated books is removed from the chamber and another container placed in the chamber for treatment.

Containers of books that have been treated can then be returned to the library for reshelving. If the relationship that existed between the books on the shelves is maintained as they are placed in the containers, it will be relatively easy to reshelf them in the same order since the relationship between the books is maintained throughout both batch and semi-continuous processes. Handling required by library personnel is therefore minimized, as is disruption in use by borrowers and researchers.

While one embodiment of the present invention has been illustrated and described, various changes may be made therein without departing from the spirit of the invention as defined by the scope of the appended claims.

WHAT IS CLAIMED IS:

1. A method of introducing a deacidifying chemical compound dissolved in a solvent into the pages of a book comprising the steps of:

reducing the residual moisture in said book to a predetermined level;

wetting said book with a solution of said compound;

subjecting said book to a vacuum; and

subjecting said book to dielectric energy to drive off said solvent.

2. The method according to claim 1, wherein the reduction of residual moisture is achieved by subjecting said book to dielectric energy.

3. The method according to claim 2, wherein the power level of the dielectric energy is related to the weight of said book.

4. A method of introducing a deacidifying chemical compound into the pages of a book comprising the steps of:

subjecting said book to a vacuum and to dielectric energy to reduce the residual moisture in said book to a predetermined level;

wetting said book with a solution of said compound in a solvent; and

driving off said solvent.

5. The method according to claim 4; wherein said solvent is driven off by subjecting said book to a vacuum and dielectric energy.

6. The method according to claim 5 wherein the power level of said dielectric energy is related to the weight of said book.

7. Apparatus for introducing a deacidification compound dissolved in a solvent into

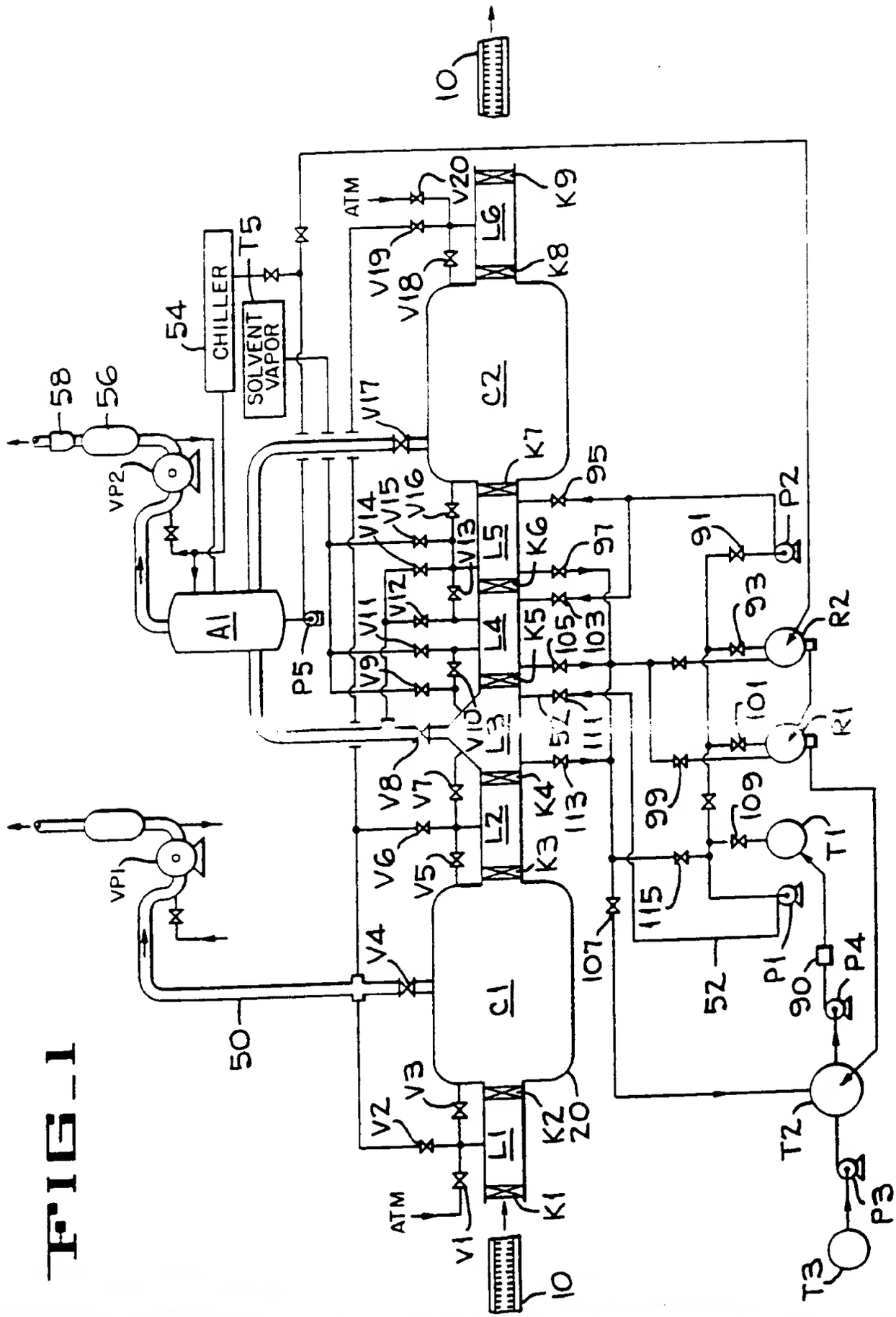
the pages of a book comprising:

vacuum chamber means capable of holding said books;

means for selectively drawing a vacuum on said chamber means;

means for selectively subjecting at least a portion of said chamber means to dielectric energy; and

means for selectively introducing said solution to and draining said solution from said chamber means.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ATM
V20
K9
L6
V19
V18
K8
T5
CHILLER
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SOLVENT VAPOR
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C2
K7
95
VP2
V14
V15
V16
V13
L5
K6
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P2
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A1
V11
V12
L4
K5
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103
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R2
P5
V9
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101
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V8
V7
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K4
113
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P4
V4
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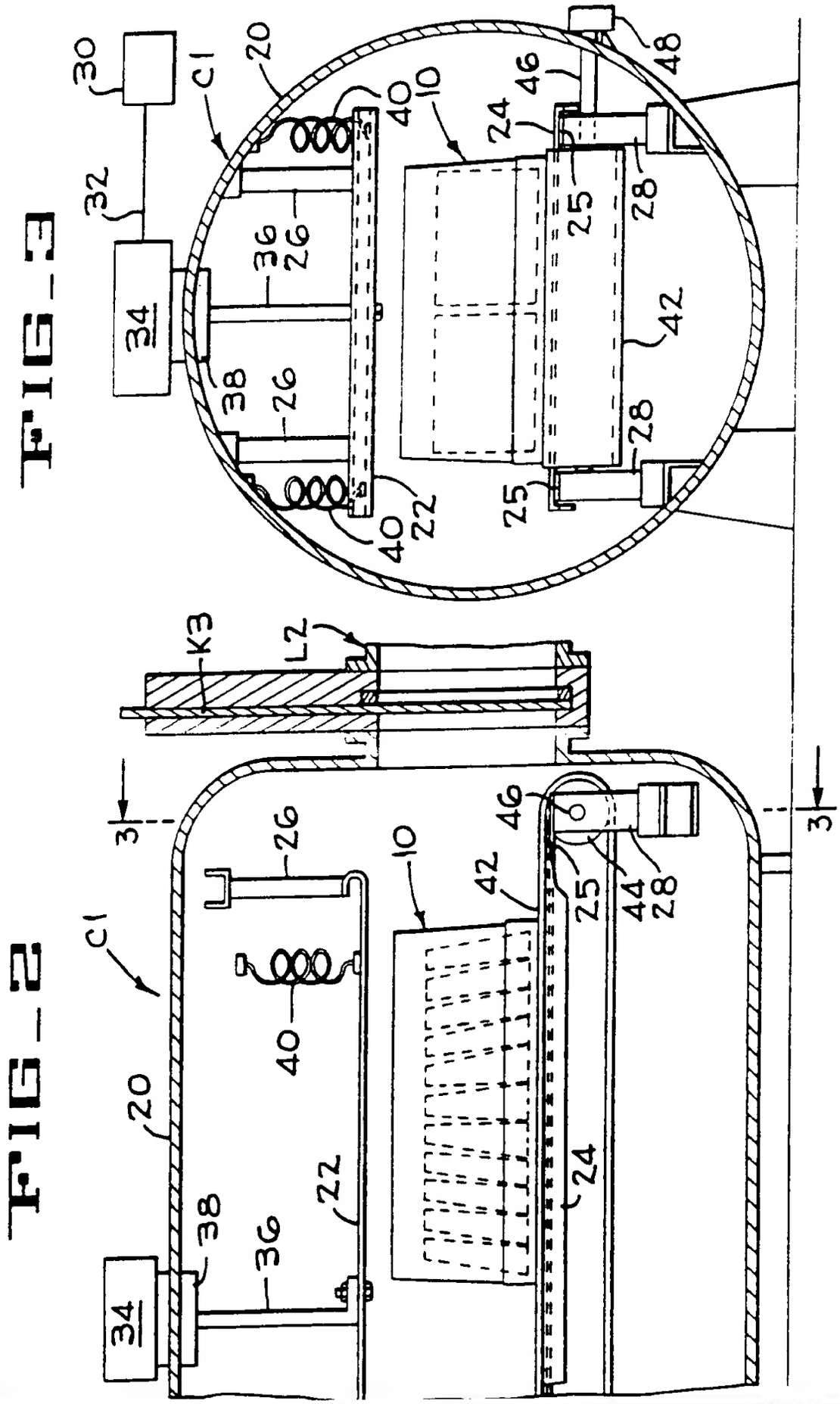
FIG_1

FIG_2


C1
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K3
L2
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FIG_3

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C1
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FIG_4

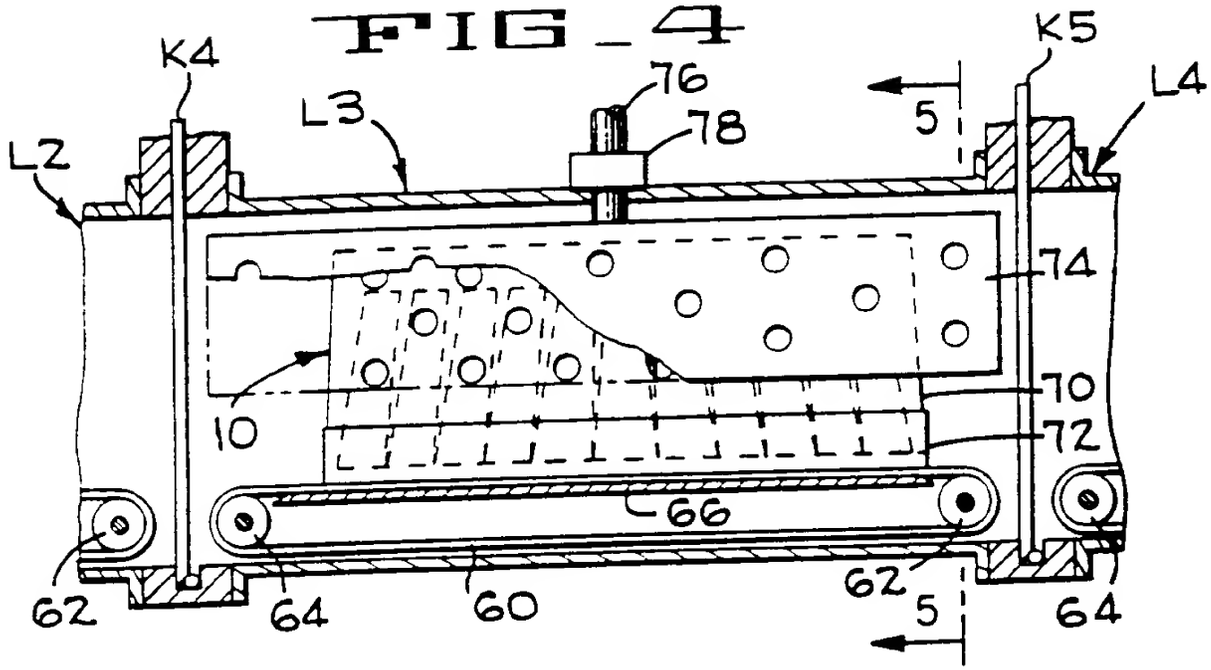
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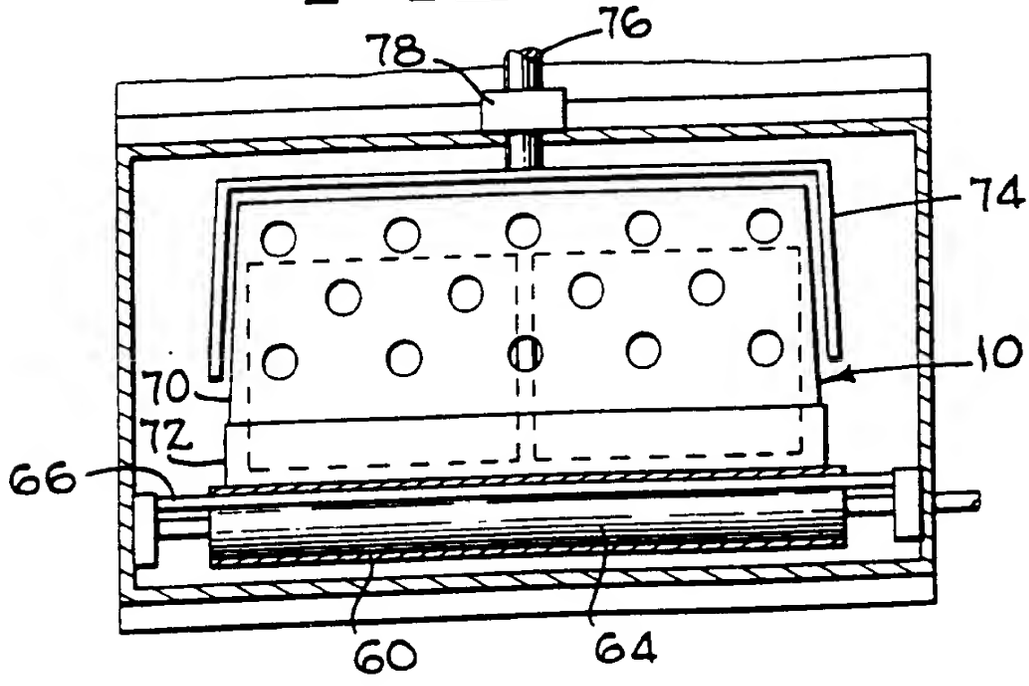
FIG_5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INTERNATIONAL SEARCH REPORT

International Application No PCT/US90/05300

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [3]

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC (5): B05D 3/06; B05C 9/14

U.S. CL: 427/296; 118/50.1

II. FIELDS SEARCHED

Minimum Documentation Searched [4]

Classification System [5]	Classification Symbols
U.S.	34/1; 118/50.1,64,423,428,429,642,643; 162/160,192; 422/22,40; 427/45.1, 296,372.2

Documentation Searched other than Minimum Documentation to the Extent that such Documents are included in the Fields Searched [6]

III. DOCUMENTS CONSIDERED TO BE RELEVANT [14]

Category *	Citation of Document, [16] with indication, where appropriate, of the relevant passages [17]	Relevant to Claim No. [18]
Y	US, A, 3,969,549 (WILLIAMS ET AL.) 13 July 1976 See col. 4, line 57- col. 5, line 37.	1-7
Y	US, A, 2,949,677 (CAMERON) 23 August 1960 See col. 1, lines 21-27, col. 2, lines 45-49, and col. 4, lines 41-52.	1-7

* Special categories of cited documents: [15]

"A" document defining the general state of the art which is not considered to be of particular relevance

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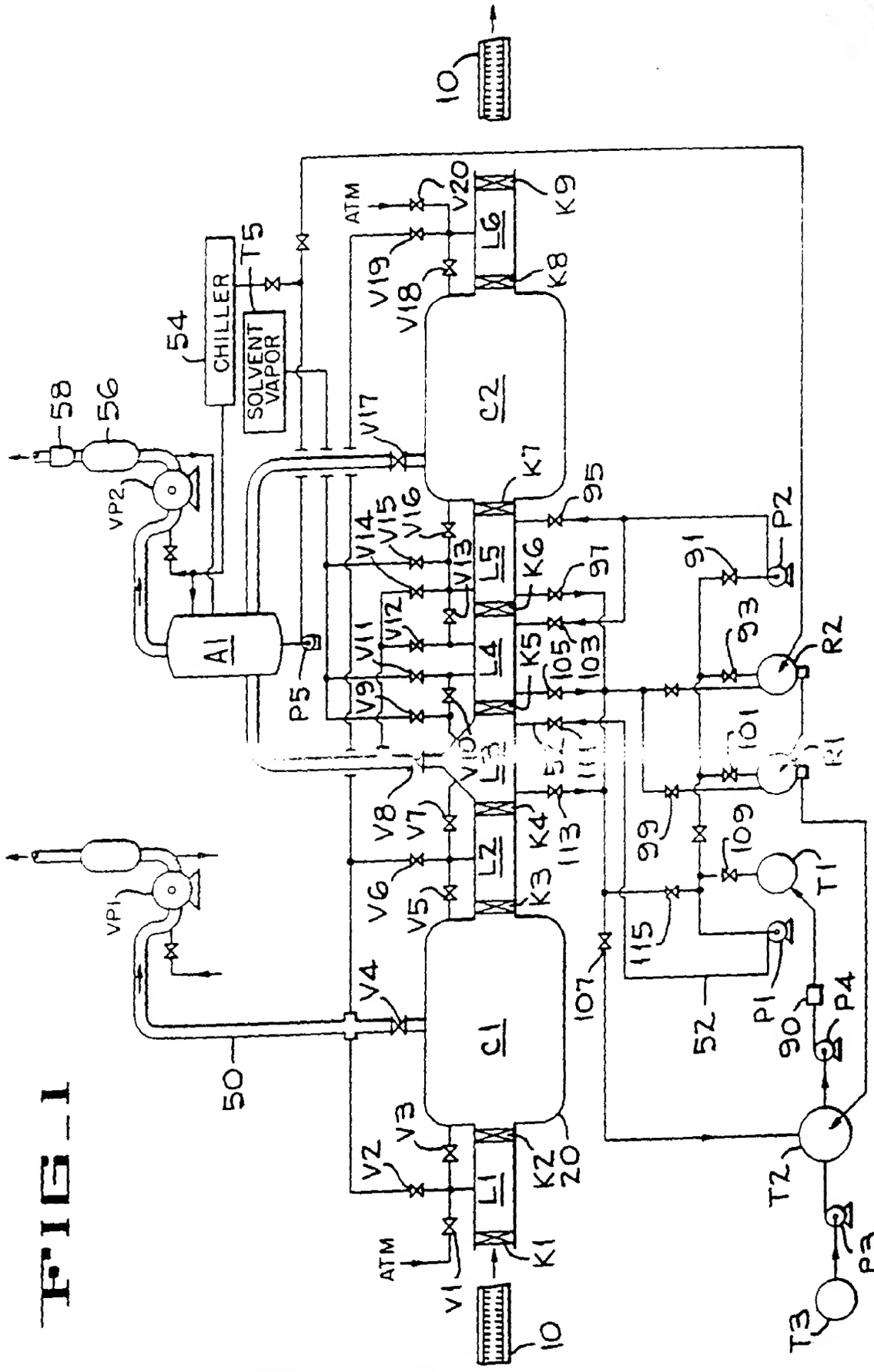
"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search [2]	Date of Mailing of this International Search Report [2]
01 NOVEMBER 1990	08 FEB 1991
International Searching Authority [1]	Signature of Authorized Officer [20]
ISA/US	TERRY J. OWENS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V8
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L2
K4
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V5
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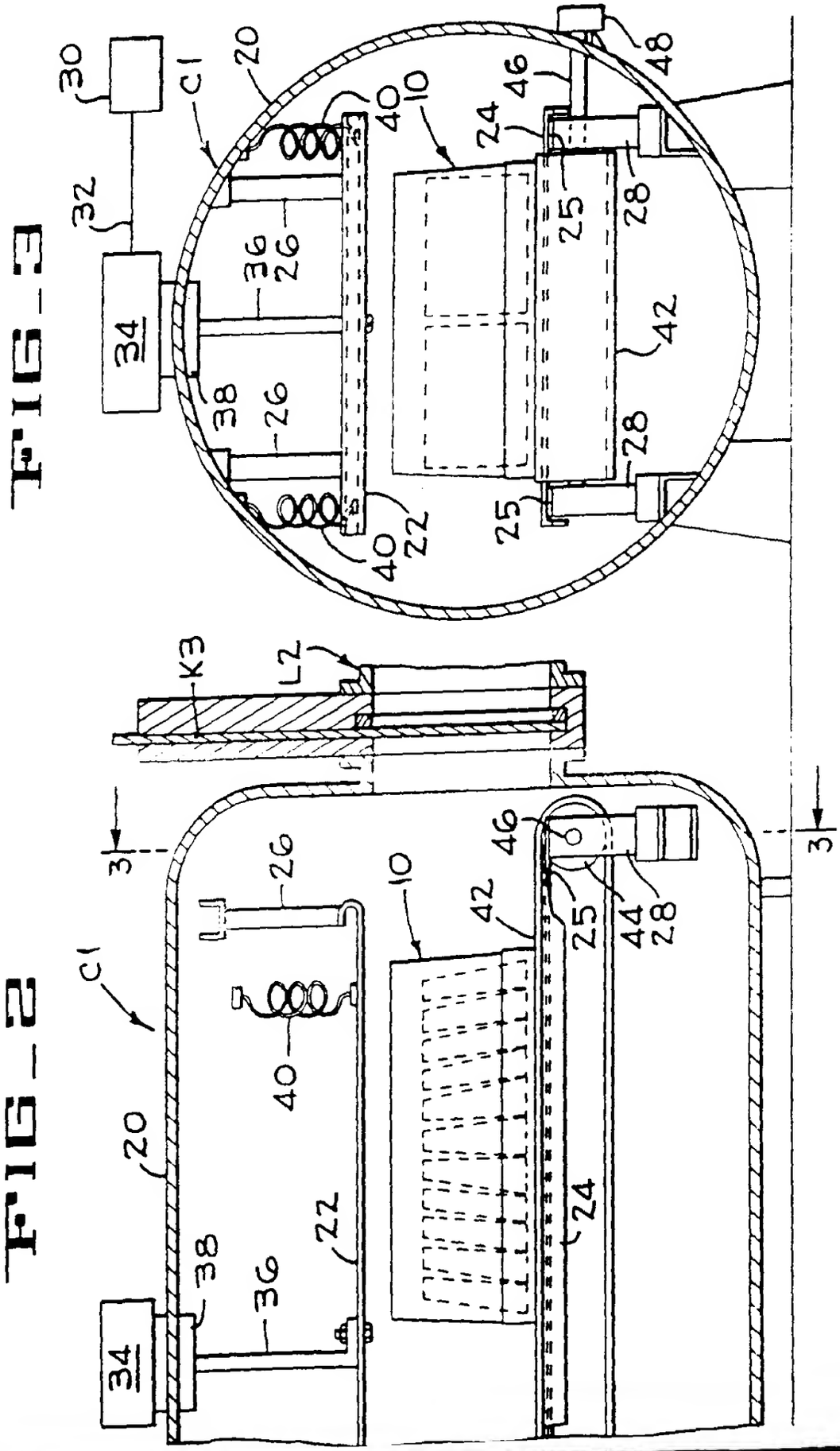
FIG-1

FIG-2


C1
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K3
L2
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FIG-3

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C1
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25

FIG_4

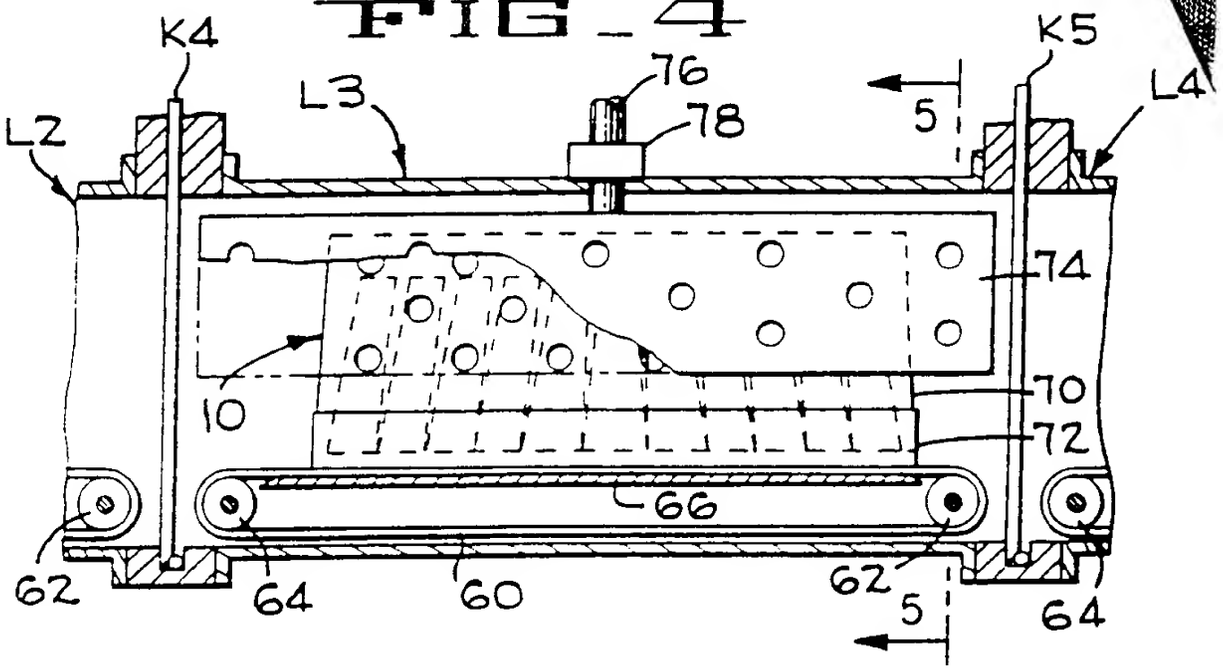
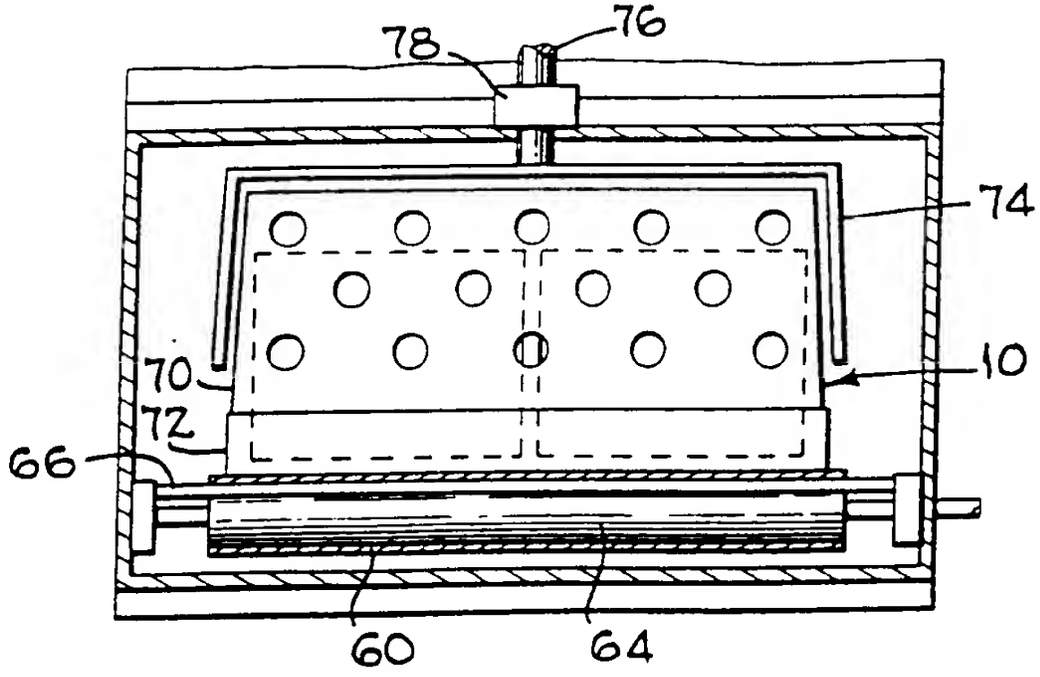

K4
K5
L2
L3
L4
76
78
5
74
10
70
72
66
62
64
60
62
5
64

FIG_5


78
76
74
70
72
10
66
60
64